

APPENDIX C

**Assessment of Adult Anadromous Salmonid
Migration Barriers and Holding Habitats in the
Upper Yuba River**

Assessment of Adult Anadromous Salmonid Migration Barriers and Holding Habitats in the Upper Yuba River



Waterfall and pool in the South Yuba River

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1.0 Introduction

In evaluating the feasibility of introducing Chinook salmon and steelhead to the upper Yuba River, the presence of potential barriers to upstream fish migration above Englebright Dam and the presence and quality of oversummering pools are important considerations. Accordingly, potential barriers and holding habitats in the upper Yuba River watershed were inventoried in a reconnaissance-level survey to document their location and extent. This technical report describes the methods and criteria used to identify potential barriers and pools for adult fish and results of the assessment.

2.0 Characteristics of Chinook Salmon and Steelhead Migration Barriers and Oversummering Holding Habitat

2.1. Migration Barriers

A variety of biological, physical, and hydraulic parameters define how features in a river channel may prevent or impede upstream migration of adult salmon and steelhead. For purposes of this assessment, the most important parameters included species (i.e., spring-run Chinook and steelhead), maturity (time in the river), site geometry, and hydraulics. These factors influence the swimming and leaping capabilities of fish (Powers and Orsborn 1985).

How barriers may affect upstream fish passage depends on if the species is a spring-run Chinook or steelhead and the level of maturity. Steelhead have greater leaping abilities than Chinook and both species have reduced leaping abilities with increased maturity or residence time in freshwater (coefficient of fish condition) (Figure 1). In California, spring-run Chinook enter streams in spring and early summer during relatively high seasonal stream flow conditions (Hallock and Fry 1967). Adult fish migrate to headwater reaches high in watersheds (when the fish have a high coefficient of condition) then reside in pools, maturing until spawning during the late summer and fall. In late summer, after holding in the river for an extended period, the fish have a lower coefficient of condition (advanced maturity) and streamflows are lower. Because adult spring-run Chinook have lesser leaping abilities than steelhead (Figure 1) and would be present during low-flow periods when hydraulic conditions at barriers would be expected to be more limited, this assessment primarily focused on that species. Additionally, unlike steelhead, adult spring-run Chinook require unique over-summering holding habitats. In the Sacramento River watershed, steelhead will migrate, hold, and spawn earlier in the season (Hallock 1989) and during higher-flow periods as compared to spring-run Chinook.

Waterfalls exceeding 11 feet in height are considered a total barrier to salmon and steelhead (Powers and Orsborn 1985). Evans and Johnston (1980), as cited by Powers and Orsborn (1985), suggest that if the height exceeds more than 6 feet it should be considered a barrier. The trajectory of the fish leap is also an important factor for passage at a potential barrier (Figure 1). Other physical parameters include, but are not limited to, depth of the plunge pool where the fish leaps and configuration of the fish exit after leaping (e.g., water depth, slope, velocity) (Figure 2). Additional factors are described in detail by Powers and Orsborn (1985).

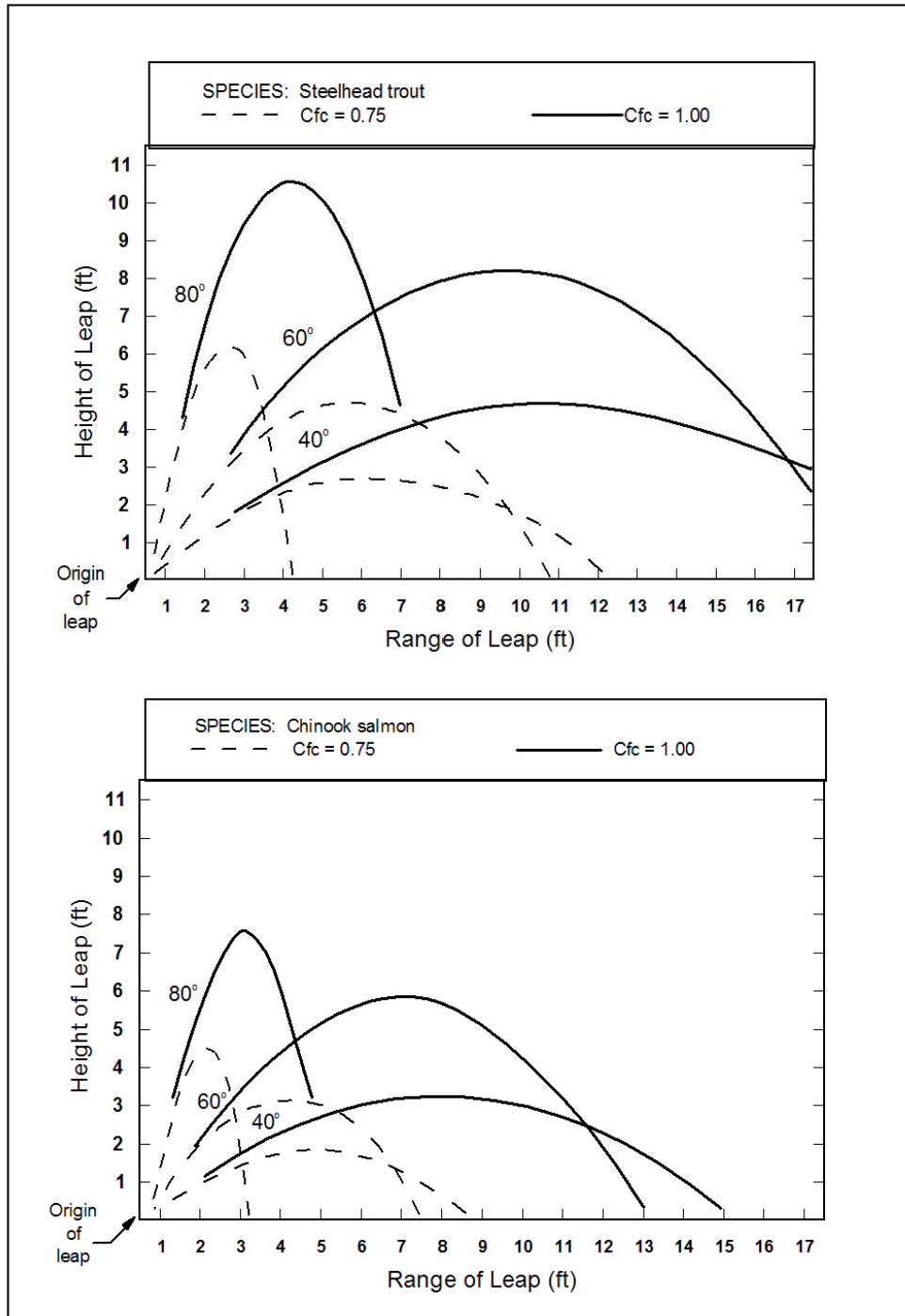


Figure 1. Leaping abilities of steelhead and Chinook salmon as related to the coefficient of fish condition (Cfc) (level of maturity and time in freshwater). Cfc = 1.00 signifies a fish in bright condition shortly after entering freshwater; Cfc = 0.75 signifies a fish that has been in the river for a short time with spawning colors apparent (adapted from Powers and Orsborn 1985).

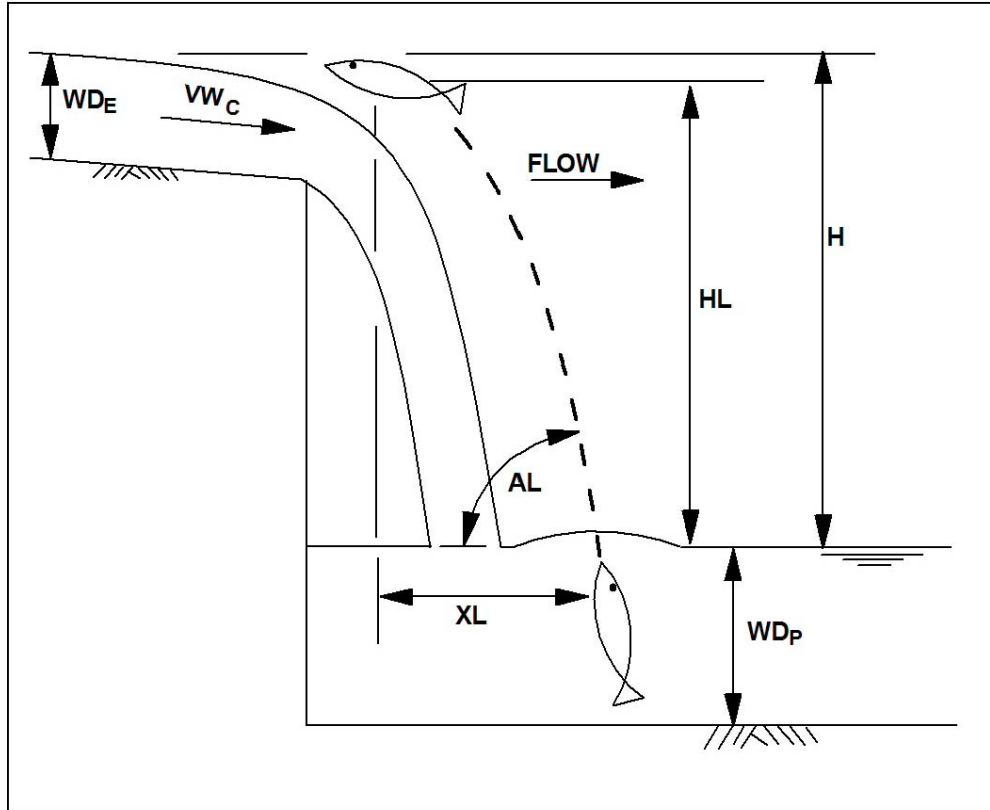


Figure 2. Some parameters that affect fish passage success at potential migration barriers. H = Change in water surface elevation, HL = Height of the fishes leap, AL = Angle in degrees from the horizontal at which the fish leaps, VW_c = Velocity of water at falls crest, XL = Horizontal distance to the maximum height of the fish leap, WD_p = Water depth of the plunge pool, WDe = Water depth at the fish exit. (Adapted from Powers and Orsborn 1985).

A combination of a potential barrier's site geometry and hydraulic conditions, along with the leaping abilities of the fish, determine how the site may affect fish passage (Figure 3) (Powers and Orsborn 1985). Therefore, the factors that may contribute to a fish migration barrier vary seasonally by hydrologic conditions and the life cycle periodicity of the particular fish species. As a reconnaissance-level survey, the features of potential barriers were estimated. Additional on-the-ground site surveys at potential barriers identified in this study would be necessary to accurately measure those features.

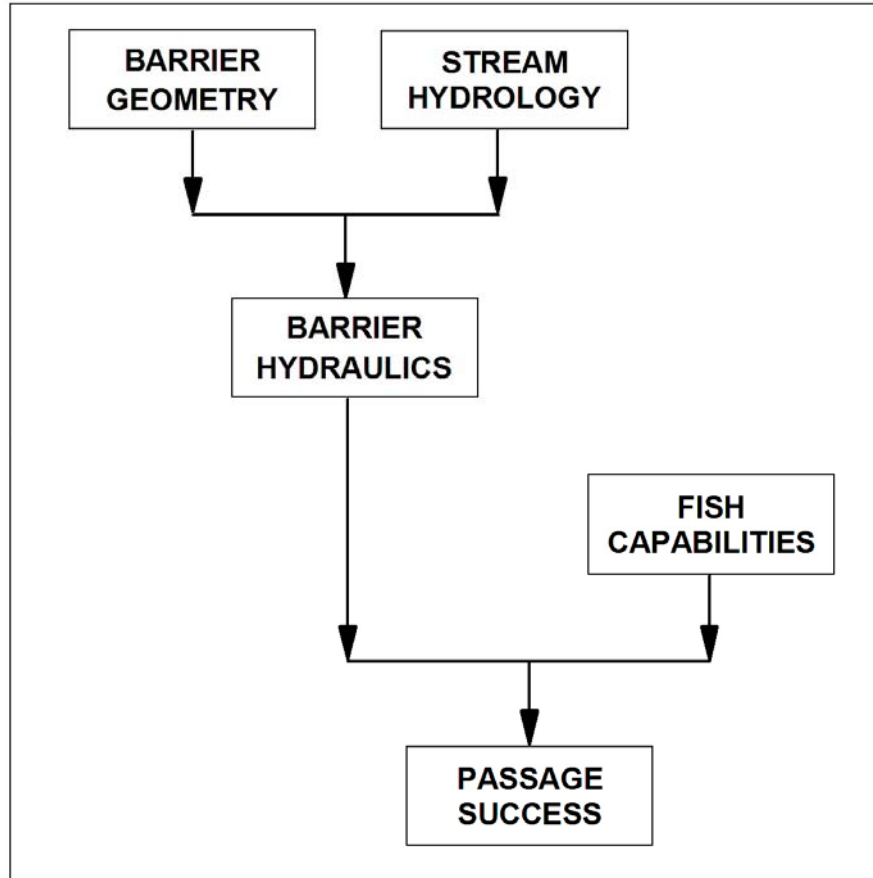


Figure 3. Flow chart for analysis of fish passage barriers. Adapted from Powers and Orsborn (1985).

2.2 Holding Habitat

Spring-run Chinook enter rivers during high-flow periods in the spring (allowing access to headwater areas) and do not spawn until the late summer and fall (Healey 1991, Moyle 2002). As a result, the adult fish must hold over in the headwater areas during the summer months before spawning. Because naturally occurring stream flows are typically low and ambient air temperatures are high in Central Valley streams during the summer, spring-run Chinook salmon require thermal refugia (areas with cooler water) in which to hold prior to spawning. This life-history trait requires that the fish hold and mature in a protected, cool-water habitat throughout the summer months.

Holding habitat attributes include:

- 1) pools sufficiently deep to allow adults to over-summer,
- 2) adequate cover, such as bubble curtains created by flowing water,
- 3) proximity to quality spawning gravel, and
- 4) adequate water temperature and dissolved oxygen (CDFG 1998)

2.2.1 Pool Depth

Pools selected by spring-run Chinook salmon are usually greater than 6 feet deep, often with bedrock bottoms and moderate velocities (Moyle 2002). Although spring-run Chinook have been found holding in shallower pools (Moyle et al. 1995), regular observations of salmon holding indicate a preference for deeper pools (McFarland 2000, Moyle 2002). The presence of adult spring Chinook in Deer Creek, California, was found to be correlated to pool depth and bedrock (Sato and Moyle 1987). The depths of pools selected by adult spring Chinook for holding can vary by watershed. Sato and Moyle (1987) found that the average maximum pool depth where these fish were found in Mill Creek, California, was 8.3 feet. Based on an extensive survey of spring-run Chinook salmon holding habitat in Deer Creek and Mill Creek, Grimes (1983) found that the average pool depth where salmon were observed was 12 feet (ranging from 8 to 19 feet) in Deer Creek and 8 feet (ranging from 4 to 12 feet) in Mill Creek. In both streams, adult spring-run Chinook salmon were consistently found in the deepest, largest pools. During the summer, Deer Creek can be exceptionally clear (e.g., 25-foot visibility) (Airola and Marcotte 1985). Visibility is considerably less in Mill Creek because of suspended material in the stream caused by snow and glacial melt from Mt. Lassen. Based on the prior work experience of members of the habitat study team in Deer and Mill creeks, the substantial difference in water clarity between the two streams is probably the principal reason for different holding habitat depth preferences. Water clarity in the Middle and South Yuba rivers during the summer is comparable to that of Deer Creek, suggesting that spring-run Chinook salmon would utilize the deeper pools.

2.2.2 Cover

Because summer flows generally have higher water clarity than during other seasons, protective cover for spring-run Chinook is particularly important. Adult fish usually hold under ledges or under bubble curtains created by water plunging into pools (Moyle 2002). Spring-run Chinook in the Salmon River, a tributary to the Klamath River, primarily used cover provided by bubble curtains and bedrock ledges (DesLaurier 1991). Based on surveys in Mill and Deer creeks, specific features commonly found where spring-run Chinook salmon over-summer include:

- Relatively deep, cool water (more than 8 to 10 feet deep, depending on water clarity)
- Overhanging structure above and within the pools (e.g., boulders, bedrock overhangs, and ledges)
- Bubble curtain and surface turbulence

Suitable cover for spring-run Chinook salmon can be provided through various combinations of these features. For example, bubble curtains are more important in

shallow pools than in pools of considerable depth. Shade can be provided through bedrock walls that overhang pools, steep canyon walls, and large boulders on the bottom of pools, where fish may seek refuge. Figure 4 shows an example of good spring-run Chinook salmon holding habitat with some of these characteristics. In very deep pools (e.g., greater than 20 feet), depth itself can provide the necessary cover.



Figure 4. Example characteristics defining good spring-run Chinook salmon holding habitat. This South Yuba River pool was measured 13-feet deep and possessed 20 percent boulders on the bottom. Note the bubble curtain at the head of the pool and the large overhanging bedrock ledge providing shade and protective cover.

2.2.3 Spawning Gravels

Proximity to suitable spawning gravels is another factor that may determine the suitability of holding habitat. In general, spring-run Chinook tend to hold in pools near spawning gravels (Moyle 2002). Sites selected by salmon and trout for redd construction are generally located just upstream of riffle crests (Lisle 1989). Salmonids select spawning sites in the stream or river where suitable water velocities, depth, and substrate are present. High water velocities are necessary to provide inducement to spawning salmon and sufficient interstitial flow through salmon redds for egg incubation (Vogel 1983). Spring-run Chinook salmon spawning substrate composition is highly variable in size, ranging from small gravel to large cobble and with gradations. Based on surveys in Mill, Deer, and Antelope creeks, spring-run Chinook spawning habitat is not easily recognizable as compared to fall-run Chinook spawning areas. Spring-run Chinook redds in these streams are often found isolated between fairly large substrate (e.g. large cobble) (McFarland 2000). Needham et al. (1943) reported that 43% of spring-run Chinook redds in Deer Creek were found in isolated areas as compared to riffle areas. In this latter

study, the average redd size was 40 square feet, which is within the smaller size range as compared to other studies of Chinook spawning reported in the literature by Healey (1991). Where suitable spawning gravels are limited near holding pools, fish may still hold in pools with the features described above and move upstream or downstream to other areas for spawning. Spring-run Chinook can exhibit a net upstream movement between pools prior to spawning (Moyle 2002). It is generally assumed that adult spring run move out of holding pools into upper reaches to spawn or remain and spawn in the tail areas of holding pools (Moyle et al. 1995). In his radio-telemetry study of Nooksack River spring-run Chinook in Washington, Barclay (1980) described a “classic” upstream movement of adult fish to spawning areas after holding for extended periods (weeks) in pools. In that study, Barclay (1980) found that adult fish may move several miles (up to about 10 miles) upstream from holding pools to spawning habitats. In Butte Creek, California, spring-run Chinook have been observed to exhibit net downstream movements from holding pools to spawning areas, but only over short distances (Ward et al. 2004). Based on the foregoing, it is assumed that spring-run Chinook will move several miles or more upstream or short distances downstream from suitable holding pools to spawning areas.

2.2.4 Water Quality (Temperature and Dissolved Oxygen)

The upper limit of optimal water temperature for adult Chinook holding during egg maturation is 59°F to 60°F (Hinze 1959, as cited by CDFG 1998). However, spring-run Chinook salmon have been observed holding at higher temperatures in Butte Creek (Ward et al. 2004). Increased water temperatures above optimal levels may not be directly lethal to adult Chinook salmon, but can have an indirect, adverse effect due to increased virulence of most diseases afflicting salmon (Boles 1988). Observations in Butte Creek suggest that disease can be a major factor in pre-spawning mortality when average daily water temperatures exceed 66°F (Ward et al. 2004). Additionally, holding at elevated temperatures can cause reduced fertility of eggs (Boles 1988). Dissolved oxygen levels should be at or above 6.0 mg/L to provide suitable conditions for adult Chinook salmon (Boles 1988).

Based on the information presented above and experience working in streams supporting spring-run Chinook salmon, it was assumed that a minimum pool depth of 10 feet would provide suitable holding habitat for spring-run Chinook salmon, but only if other important habitat features (e.g., shade, overhanging cover, bubble curtain, cool water temperatures, suitable levels of dissolved oxygen, and spawning areas) were present. This premise is conservative because spring-run Chinook have been observed holding in some pools not possessing those attributes (C. Harvey, CDFG, pers. comm.). The significance of this assumption is that, if anadromous salmonids are re-introduced into the upper Yuba watershed, the available pools for holding fish (in those areas where water temperatures are suitable) would likely be higher than that found during this study.

Because this was a reconnaissance-level survey, potential holding habitat characteristics were estimated. Additional on-the-ground surveys of pools identified in this study would be necessary to accurately measure depths, cover, water quality, and proximity to spawning habitat.

3.0 Assessment Methods

3.1 Migration Barriers

The locations of potential upstream migration barriers for adult Chinook salmon and steelhead were identified through low-altitude aerial (helicopter) videography taken in October 2002 during low-flow (< 50 cfs) conditions. Only those potential barriers affecting adult fish were identified; potential barriers for movements of small or juvenile fish were not included in this assessment. The latitude and longitude coordinates of the helicopter were recorded on the video image to allow subsequent mapping of barrier and pool locations. The average speed and height of the helicopter was 15 to 25 mph and 100 to 150 feet above ground, with higher speeds and above-ground elevations in upper portions of the watersheds (Barclay 2002). In most instances, the clarity of the aerial videography was sufficient to show site-specific conditions to judge if the site geometry may pose a potential barrier to upstream migration (e.g., Figure 5). There were some instances where the aerial video was insufficient to see the barrier adequately because of line-of-site limitations (e.g., shadows, canyon walls), speed of the helicopter, or video clarity. These latter instances primarily occurred in the upper-most reaches of the Middle and South Yuba rivers where helicopter flight was more difficult (e.g., higher elevation, narrow canyon walls).

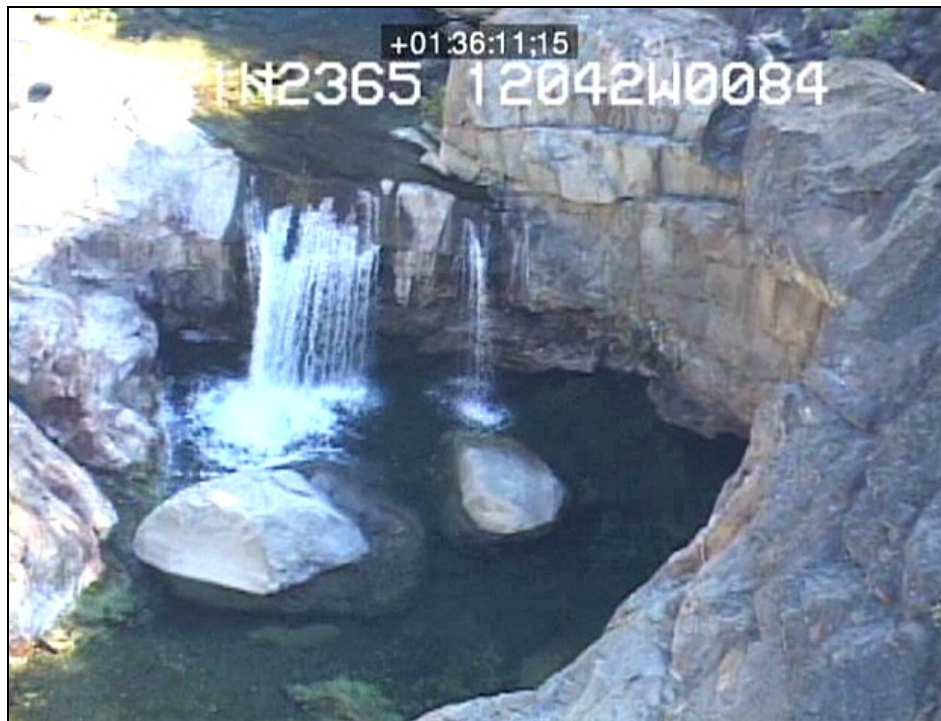


Figure 5. Picture obtained by screen capture from the October 2002 aerial videography. Falls shown is on the South Yuba River and was estimated 15 feet in height from the aerial view and measured 17 feet in height during the on-the-ground site visit.

Because conditions at potential barriers change significantly between low and high river flows, a second aerial survey of some sites in the Middle and South Yuba rivers was performed in June 2003 during high-flow (> 500 cfs) conditions. Figures 6 and 7 provide an example of how conditions can change between low and high river flows. Of particular importance in this assessment were factors such as estimated height of the barriers, plunge pool characteristics, and physical configuration of the barriers (e.g., single or multiple falls, complexity of the falls, chutes, or cascades, fish passage routes, etc.). The leaping abilities of each species (see Figure 1) were compared to the site characteristics to estimate how the site may or may not affect fish passage.



Figure 6. Falls on the South Yuba River during low-flow conditions.



Figure 7. Same falls shown in Figure 6, during high-flow conditions.

Because the characteristics of fish barriers vary with changing stream flow and this assessment was primarily based on observations during low-flow conditions, the findings in this report are limited. The interaction between increased stream flow and barrier site geometry changes hydraulic conditions in complex ways. As discussed in a later section, an accurate determination of some potential barriers would require more extensive site-specific field surveys.

The height of potential barriers could only be estimated and not measured from the helicopter video. On-the-ground site visits were conducted at several sites during August 2003 and August 2005 during low-flow (< 100 cfs) conditions to acquire data on the site geometry using an electronic clinometer, infrared range finder, and measuring tapes (Figure 8) using basic survey techniques such as those described by Clay (1995). Plunge pool characteristics were estimated from the video to assess if sufficient depth was available for leaping fish. For example, if it was evident from the video that the falls cascaded onto boulders in shallow water, those conditions would significantly increase the difficulty for successful fish passage. In situations where it was feasible, an underwater examination by snorkeling was made to determine characteristics of the plunge pool that may affect fish passage (Figure 9).



Figure 8. Member of the habitat assessment team measuring the height of a falls on the South Yuba River.



Figure 9. Member of the habitat assessment team examining the characteristics of a plunge pool at a falls on the South Yuba River.

Most of the barriers were located in the upper portions of each river where the topographic relief adjacent to the river channel is more extreme. In most instances, this required swimming in the main river channel to gain access to the several areas examined during on-site visits (Figure 10). Other areas (such as the box canyons on the Middle Yuba River and a series of multiple falls a short distance downstream of Lake Spaulding on the South Yuba River) were inaccessible; therefore, assessments in those areas were based on the two aerial surveys performed in October 2002 and June 2003.



Figure 10. Member of the habitat assessment team swimming to a barrier site when stream-side access was not possible.

3.1.1 Flow Analysis

Because stream flow magnitude during the principal period of salmon migration is an important parameter determining if fish can successfully negotiate passage at a potential barrier, daily flow records were examined for both the Middle Yuba River (1969 through 1999 water years) and South Yuba River (1960 through 1999 water years). For the Middle Yuba River, the estimated flows upstream of Our House Dam (composite of the gage below Our House Dam [USGS 11408880] and the Camptonville Tunnel [USGS 11409350]) were used. For the South Yuba River, flow records at the Jones Bar gage (USGS 11417500) were used. Because flow conditions are naturally cyclical, the daily flows were examined based on wet, above-normal, below-normal, dry, and critically dry annual hydrologic conditions.

3.2 Adult Salmon Holding Habitats

The locations of potential adult holding habitat for Chinook salmon were identified through low-altitude aerial videography taken in October 2002 (previously described). In most instances, the clarity of the aerial videography was sufficient to show site-specific conditions to judge if the pools could serve as potential holding habitat for salmon. There were some instances where the aerial video was insufficient to see a pool adequately because of line-of-site limitations (e.g., shadows, canyon walls, speed of the helicopter). These latter instances primarily occurred in the upper-most reaches of the Middle and South Yuba rivers where helicopter flight was more difficult (e.g., higher elevation, narrow canyon walls). It is important to note the limitations of the aerial survey in classifying the suitability of pools for holding habitat because the assumptions on suitability of holding pools were conservative (discussed later in this report).

The depths of potential salmon holding pools could only be estimated and not measured from the helicopter video. On-the-ground site visits were conducted at several pools in the Middle and South Yuba rivers during August 2003. August was assumed to be the period when holding habitat may be most limiting due to low flows and high water temperatures. The habitat team used snorkeling to identify characteristics in several pools (Figure 11). Because of the high water clarity and low flows, all features of those pools examined during site visits could be easily determined. Depth measurements were



Figure 11. Member of the habitat assessment team snorkeling in a 17-foot deep pool in the South Yuba River

obtained by use of a weighted measuring tape. Notes were taken on other characteristics that may be important for holding habitat (e.g., shade, bubble curtain, ledges, and

boulders). To determine potential thermal stratification in pools, a thermometer was placed on the bottom for approximately 5 minutes, read underwater on the bottom, and compared to temperature readings observed at the surface of the pools.

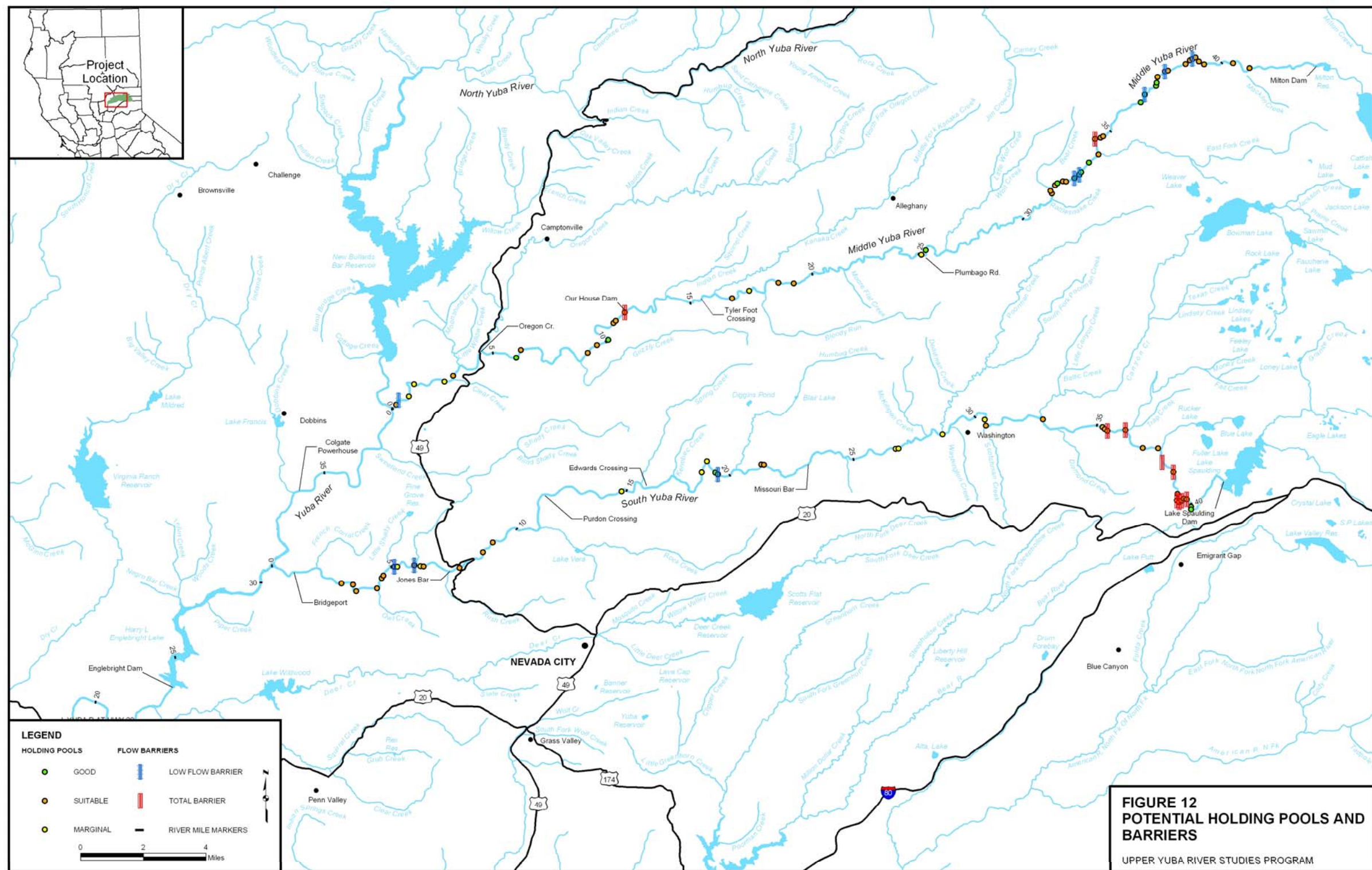
4.0 Assessment Findings

4.1 Migration Barriers

Based on the aerial videography and field surveys, 24 potential barriers to upstream fish migration were identified (Figure 12 and Appendix Tables 1 and 2 at the end of this report). On the Middle Yuba River, 6 sites were considered to be barriers to upstream passage only during low-flow conditions; 2 additional sites were considered to be total barriers, regardless of flow conditions. On the South Yuba River, 3 sites were considered only low-flow barriers; 12 sites were judged to be total barriers at both low and high river flows. Most of the barriers were located in the upper portions of each drainage (Figure 13), where the topographic relief adjacent to the river channel is more extreme than that of the downstream portions. The several barriers examined during on-site visits are noted in the appendices.

For purposes of this assessment, barriers were defined according to predicted responses of salmon and steelhead at the sites during low-flow (< approx. 100 - 200 cfs) and high-flow (> approx. 100 - 200 cfs) conditions. These definitions were somewhat subjective and based on professional judgment. At those sites considered low-flow barriers, it was estimated that upstream migration of salmon could occur at flows exceeding approximately 100 to 200 cfs because of changes in hydraulic conditions more favorable for fish passage such as increased plunge pool depths and rise in tailwater elevations (e.g., Figure 14). More detailed analyses of each site, including measurements taken during higher-flow conditions than that observed during the low-flow site visits, would be necessary to determine passage conditions (discussed in a subsequent section).

The low-flow barriers could be physically altered to provide unobstructed fish passage. It is important to note that both the Middle and South Yuba river channels experience periodic changes (e.g., bedload movement, rock slides). If anadromous salmonids are re-introduced to the upper Yuba watershed, periodic maintenance of some sites will likely be necessary to ensure suitable fish passage conditions (e.g., moving large boulders, modifying the localized channel gradient, raising tailwater elevations, etc.).



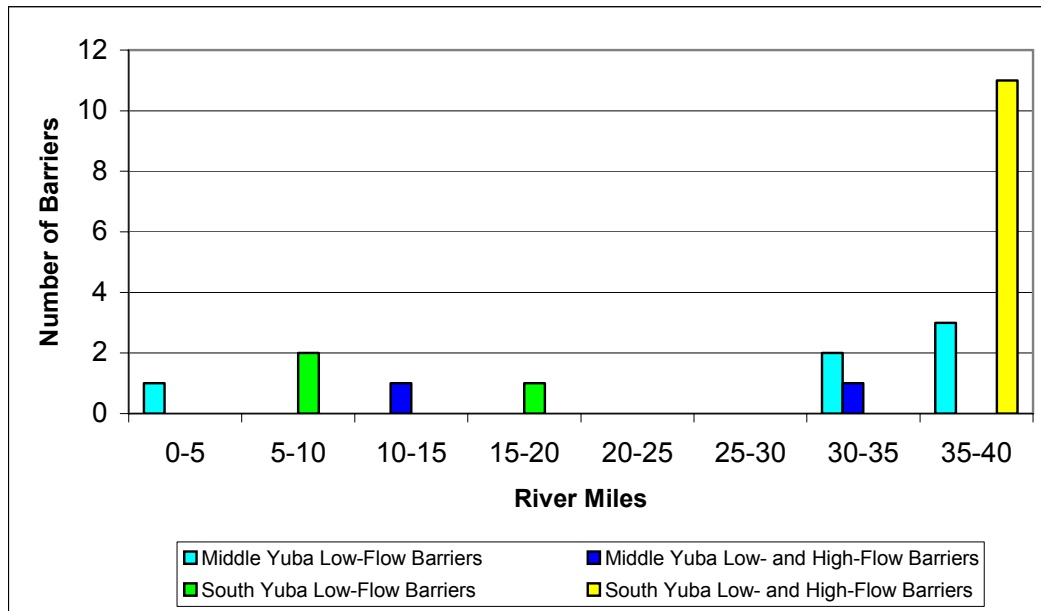


Figure 13. Number of potential barriers to spring-run Chinook salmon migration on the Middle and South Yuba rivers.



Figure 14. Falls on the Middle Yuba River (RM 0.4) estimated to be a low-flow barrier because of a combination of height, channel geometry, shallow plunge pool, and unsuitable conditions upstream of the falls. This hydraulic control was assumed to not be a high-flow barrier because of estimated increased plunge pool depth, rise in tailwater elevation, and a downstream hydraulic control that would decrease height of the falls anticipated with higher flow.

The estimated number of barriers should be considered as conservative because the habitat study team was not able to access some sites. Additionally, some barriers may not have been discerned from the helicopter video because of factors previously described. The downstream-most total barrier to migration on the Middle Yuba River is Our House Dam, located near river mile 12. Above Our House Dam, the next total barrier to migration was located at RM 34.4. On the South Yuba River the downstream-most total barrier was located at RM 35.4. Migration of adult spring-run Chinook salmon and steelhead to areas above these barriers would be impossible without modification or provision of passage facilities.

4.1.1 Salmon Migration Timing and Seasonal Hydrology

Because the magnitude of stream flow is an important factor determining if fish can migrate past potential barriers, the flow regimes in the Middle and South Yuba rivers were compared to periods when adult spring-run Chinook salmon may be expected to migrate. There are only limited data on specific run timing for spring-run Chinook salmon in the Sacramento River basin. Counts of salmon migrating past the Red Bluff Diversion Dam on the Sacramento River are unlikely to be of value in estimating spring-run Chinook migration timing because the salmon probably do not possess characteristics of true spring run (i.e., introgression with fall run) (Vogel and Rectenwald 1987). However, Mill and Deer creeks possess spring-run Chinook populations and some limited data are available for those tributaries to the Sacramento River. In daily counts at fish ladders on Clough Dam on Mill Creek during 1984 (Fisher 1984) and 1986 (Vogel 1987a) and Stanford-Vina Dam on Deer Creek during 1986, (Vogel 1987b) it was determined that the principal adult spring-run migration period occurred from April through June, with most migration occurring during May and early June (Figure 15), which is similar to incomplete counts in Deer Creek during the 1940s (Table 1).

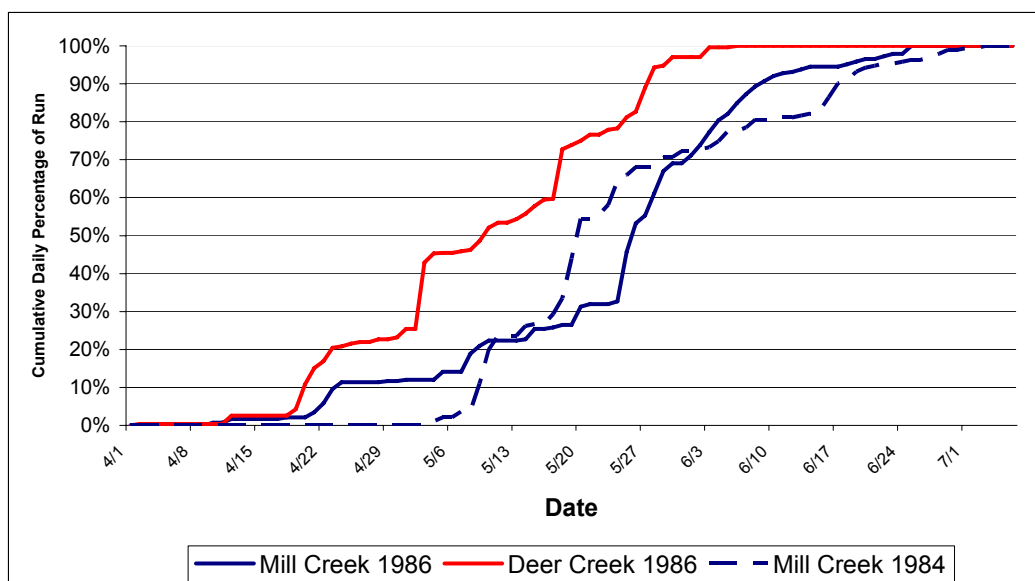


Figure 15. Counts of adult spring-run Chinook salmon migrating upstream in Mill Creek, 1984 and 1986, (Fisher 1984, Vogel 1987a) and Deer Creek, 1986 (Vogel 1987b).

Table 1. Incomplete counts of spring-run Chinook in Deer Creek, 1940 – 1948 (from Cramer and Hammack 1952).		
Year	Period	Peak Period
1940	April 12 – May 22	---
1941	May 20 – July 6	June 4 – 15
1942	May 13 – July 2	June
1943	February 20 – June 16	April
1944	January 1 – June 30	April
1945	April 13 – June 23	May
1946	April 11 – June 19	May
1947	April 11 – May 15	May
1948	May 11 – June 30	May

In its status review of spring-run Chinook in the Sacramento River, the California Department of Fish and Game developed an estimated composite run timing for spring Chinook based on historical records for Mill and Deer creeks, Feather River, and the upper Sacramento River prior to the construction of Shasta Dam. Those data indicate that the principal period of migration occurred during May to mid-June (Figure 16). Based on this information, an assumed primary run timing of May to mid-June was used to compare with historical flow records for the Middle and South Yuba rivers. Because a small portion of the spring run migration occurs during April and July, those months were also included in the analysis.

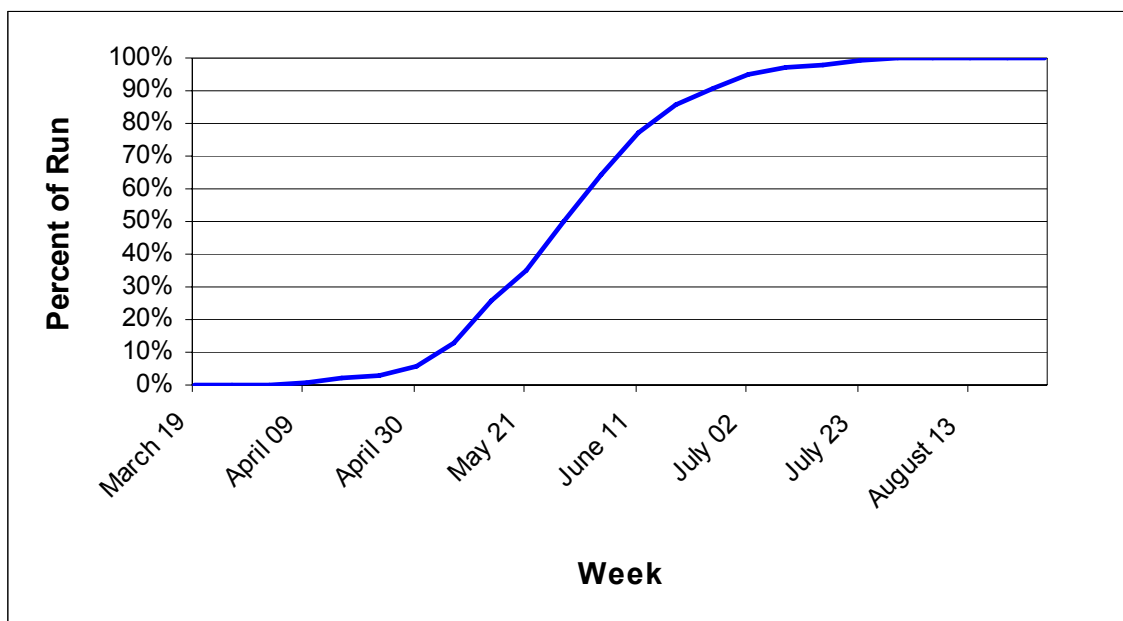


Figure 16. Run timing for spring-run Chinook salmon as based on a composite of historical data from Mill and Deer creeks, Feather River, and the upper Sacramento River prior to the construction of Shasta Dam (adapted from CDFG 1998).

The average daily flows in the Middle Yuba River in wet and above-normal hydrologic conditions were greater than 200 cfs during the majority of the assumed spring-run Chinook salmon migration period. However, during below-normal, dry, and critically dry conditions, average daily flows were generally less than 200 cfs during the early portion of spring-run Chinook migration and less than 100 cfs during the later portion of the migration period (Figure 17). It should be noted that the flows in the Middle Yuba were estimated for a location upstream of Our House Dam; therefore, the flows at the low-flow barrier downstream at RM 0.4 would be less than shown here due to diversions into the Camptonville Tunnel at Our House Dam. Because of the natural variability in daily flows, there could be short periods of increased flows providing suitable passage conditions for spring run. For example, the historical records for dry hydrologic conditions show that there were intervals when increased flows above 200 cfs occurred during the middle of the spring-run migration period (Figure 17). Surges in adult spring run migration appear to occur after rain events causing slight turbidity increases (Moyle et al. 1995).

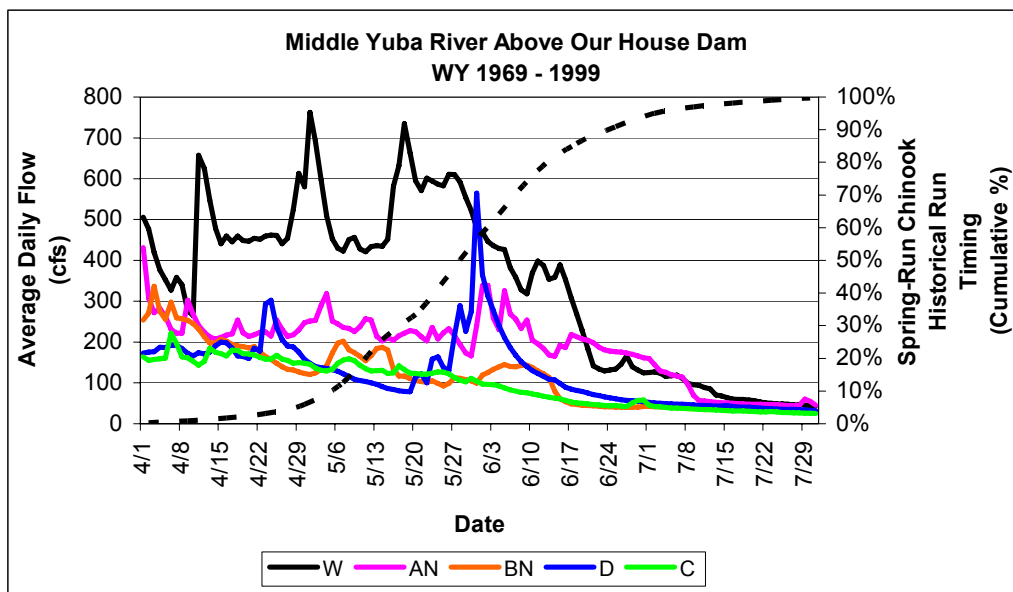


Figure 17. Average daily flow (cfs) in the Middle Yuba River upstream of Our House Dam during wet (W), above-normal (AN), below-normal (BN), dry (D), and critically dry (C) hydrologic conditions.

Daily flow records for the South Yuba River indicate that daily flows would probably provide suitable passage at low-flow barriers in wet, above-normal, and below-normal hydrologic conditions during the majority of the spring-run migration period (Figure 18). Except for brief periods, flows in dry and critically dry conditions may be marginal for suitable fish passage.

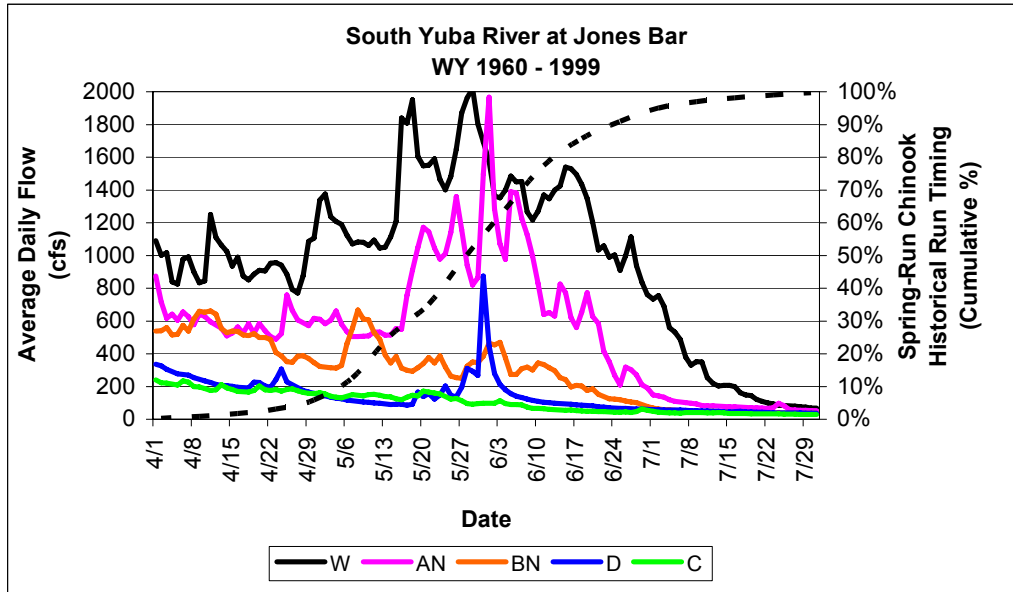


Figure 18. Average daily flow (cfs) in the South Yuba River at Jones Bar during wet (W), above-normal (AB), below-normal (BN), dry (D), and critically dry (C) hydrologic conditions.

These historical flow records suggest that the magnitude of flow could be problematic for spring-run Chinook migration in the Middle and South Yuba rivers, depending on hydrologic conditions. As the migration season progresses, the salmon's coefficient of condition decreases, resulting in significantly reduced leaping abilities (see Figure 1) to negotiate low-flow barriers. During years of naturally occurring low flows, only the earliest-returning spring-run Chinook may be able to migrate past some of the low-flow barriers unless physical alterations were made to those sites to allow unobstructed fish passage.

Further detailed, site-specific data and analyses would be needed to determine those flows allowing fish passage at these barriers. For example, Figure 2 shows some of the physical parameters affecting fish passage that could be measured at each site under different flow conditions. Detailed surveys of the channel geometry and hydraulic measurements (e.g., water depths and velocities) at a variety of flows would provide data to determine the level of flow necessary to provide suitable passage conditions. Powers and Orsborn (1985) provide details on the type of site-specific analyses that should be performed to determine conditions for fish passage at migration barriers. Based on the reconnaissance survey, physical alteration of the low-flow barriers to accommodate fish passage is probably more feasible than flow augmentation.

4.2 Holding Habitat

Based on the aerial videography and field surveys, 53 pools in the Middle Yuba River and 48 pools in the South Yuba River had the required physical characteristics (not accounting for water temperatures) necessary to function as holding habitat for spring-run Chinook salmon (Figure 12 and Appendix Tables 1 and 2 at the end of this report). The several pools examined during on-site visits are noted in the appendices. Most of the

potential pools judged to provide suitable holding habitat were in the upper portion of both rivers (Figure 19). Although these areas possess the desirable physical characteristics of spring-run Chinook salmon holding habitat (depth and cover), many of the sites may have summer water temperatures above the thermal preference. For example, cooler pools were found in the upper reaches of each drainage, but water temperatures exceeded the optimal conditions for Chinook salmon (greater than 59°F) in all areas. No thermal stratification was found, even in the deepest (35 feet) pool, suggesting that thermal refugia may be limited in the upper Yuba River watershed. During surveys of spring-run Chinook holding pools in Deer Creek, the U.S. Forest Service also did not find any evidence of water temperature stratification (USFS unknown date). Even though many of the pools observed in the Middle and South Yuba rivers had depths greater than or equal to 10 feet, they were considered unsuitable holding habitat because most of the other necessary features were not found (e.g., shade, overhanging cover, and bubble curtain). The significance of this conservative assumption is that, if anadromous salmonids were re-introduced to the upper Yuba watershed, the fish may use additional habitats beyond those identified in this assessment.

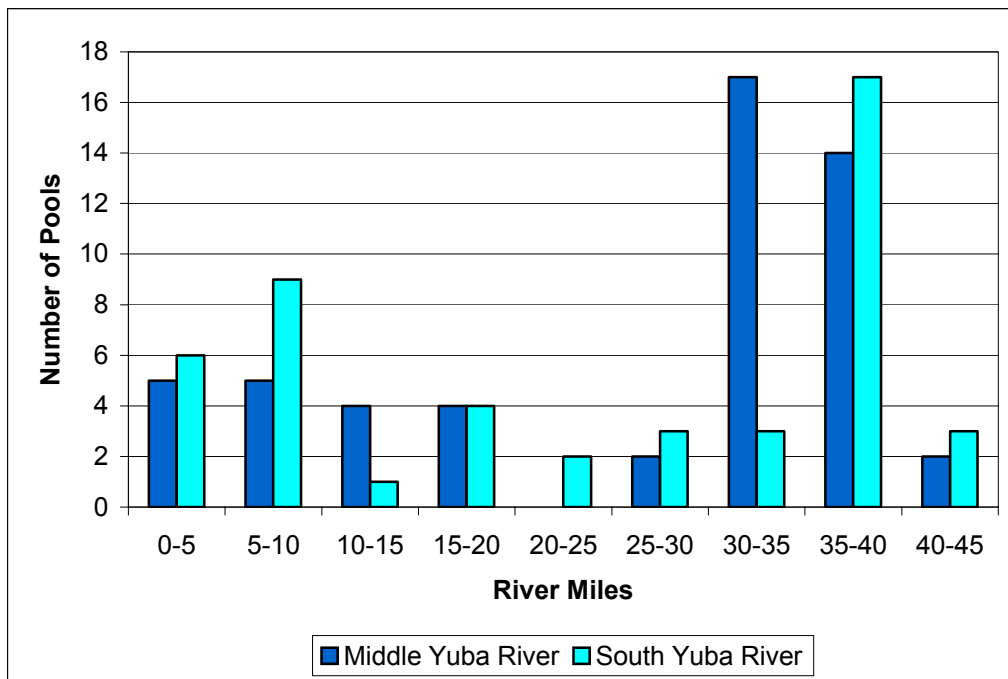


Figure 19. Number of pools possessing spring-run Chinook salmon holding habitat characteristics (not accounting for water temperature) in the Middle and South Yuba rivers.

In general, each holding pool identified in this survey could probably support 50 to 100+ adult fish (if water temperatures were suitable). This assumption is based on observations of adult spring-run Chinook in Mill, Deer, and Butte creeks. Holding densities of spring run in Butte Creek have been observed to be substantially higher, so this assumption is likely conservative.

Some areas in the upper Yuba River watershed that could provide suitable holding habitat may not have been identified during the surveys. These include inaccessible areas that

could not be adequately observed during the aerial surveys, and areas where physical characteristics would significantly change with increased stream flows. Depending on site-specific conditions, stream flows higher than those occurring during the surveys would be expected to improve habitat attributes, such as water depth and bubble curtains. Therefore, based on the previously stated caveats and absent water temperature limitations, the results presented here should be considered conservative estimates of potential holding habitat for adult spring-run Chinook salmon in the upper Yuba River watershed.

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Appendix Table 1. Potential pools and barriers for spring-run Chinook salmon and steelhead in the Middle Yuba River.							
Name	Latitude Deg (N)	Latitude Minutes	Longitude Deg (W)	Longitude Minutes	RM Loc	Feature	Comments
1-LB	39	22.3314	-121	7.9287	0.4	low-flow barrier	site visit, 2 falls in series, lower falls 9 feet, upper falls 6 feet, shallow (<3 feet) plunge pool
2-P	39	22.2315	-121	8.0721	0.2	pool	est. 8-10 feet deep, bubble curtain, numerous boulders, steep bedrock walls, shade, suitable holding habitat
3-P	39	22.4537	-121	7.6038	0.8	pool	est. at least 10 feet deep, numerous boulders, steep bedrock walls, shade, suitable holding habitat
4-P	39	22.7899	-121	7.4905	1.5	pool	est. 10 feet deep, bedrock sloping wall on left bank, boulders, fairly exposed, bubble curtain only with higher flows, marginal holding habitat
5-P	39	22.848	-121	6.3806	2.6	pool	est. 10 feet deep, bedrock sloping wall on both banks, boulders, fairly exposed, bubble curtain only with higher flows, spawning riffle at d/s end, marginal holding habitat
6-P	39	22.9648	-121	6.0419	3	pool	narrow trench pool over 10 feet deep, steep bedrock walls on both banks, boulders, suitable holding habitat
9-P	39	23.4634	-121	3.898	5.8	pool	narrow trench pool over 10 feet deep, steep overhanging bedrock walls on both banks, good bubble curtain, good holding habitat
10-P	39	23.6196	-121	3.6118	6.1	pool	narrow trench pool over 10 feet deep, steep bedrock walls on both banks, boulders, suitable holding habitat
12-P	39	23.5763	-121	1.23	9.3	pool	sloping bedrock walls on both banks, boulders, bubble curtain, boulders, narrow trench pool, suitable holding habitat
13-P	39	23.7755	-121	0.9481	9.7	pool	est. more than 10 feet, narrow trench pool with bedrock walls on both banks, suitable holding habitat, in shadow
13A-P	39	23.8083	-121	0.9111	9.7	pool	est. more than 10 feet, narrow trench pool with bedrock walls on both banks, small bubble curtain, suitable holding habitat

Appendix Table 1. Potential pools and barriers for spring-run Chinook salmon and steelhead in the Middle Yuba River.							
Name	Latitude Deg (N)	Latitude Minutes	Longitude Deg (W)	Longitude Minutes	RM Loc	Feature	Comments
14-P	39	23.9753	-121	0.4448	10.1	pool	est. over 20 feet deep, very large and long pool on river bend, steep bedrock wall on right bank, good holding habitat
15-P	39	24.3484	-121	0.3399	11.5	pool	trench pool in shadow, may be at least 10 feet deep, narrow canyon, in shade, some bubble curtain, est. suitable holding habitat
16-P	39	24.4151	-121	0.2622	11.6	pool	est. more than 10 feet, trench pool with bedrock walls on both banks, small bubble curtain, boulders, suitable holding habitat
18A-P	39	24.6345	-120	59.9431	12	pool	site visit, deep pool (est. more than 15-20 feet d/s dam, suitable holding habitat
18-TB	39	24.6345	-120	59.9431	12	low- & high-flow barrier	site visit, est. dam height at spillway approx. 52 feet high, total barrier
21-P	39	25.0787	-120	56.1072	16.6	pool	est. at least 10 feet, suitable holding habitat, steep overhanging berock, bubble curtain, boulders
23-P	39	25.2469	-120	55.3826	17.4	pool	small trench area at least 10 feet deep, with steep bedrock and some boulders, marginally suitable holding habitat
24-P	39	25.4697	-120	54.3107	18.8	pool	at least 10 feet deep, numerous boulders, steep bedrock walls, shade, suitable holding habitat
25-P	39	25.4477	-120	53.7296	19.3	pool	close to 10 feet deep, large bouders overhanging, bubble curtain, small but suitable holding habitat
28-P	39	26.2073	-120	49.178	25.1	pool	small pool close to 10 feet deep, with steep bedrock on left bank, some boulders, and small bubble curtain, marginally suitable holding habitat
29-P	39	26.3487	-120	49.0522	25.4	pool	narrow trench pool over 15 feet deep, steep overhanging bedrock walls on both banks, bubble curtain, good holding habitat
32-P	39	27.8572	-120	44.5214	31.6	pool	est. at least 10 feet deep, bedrock walls, numerous boulders, small bubble curtain, suitable holding habitat
33-P	39	27.9612	-120	44.6092	31.7	pool	est. at least 10 feet deep, bedrock wall, numerous

Appendix Table 1. Potential pools and barriers for spring-run Chinook salmon and steelhead in the Middle Yuba River.							
Name	Latitude Deg (N)	Latitude Minutes	Longitude Deg (W)	Longitude Minutes	RM Loc	Feature	Comments
							boulders, small bubble curtain, suitable holding habitat
34-P	39	28.1096	-120	44.3889	32	pool	est. at least 10 feet deep, bedrock wall, numerous boulders, small bubble curtain, suitable holding habitat
35-P	39	28.1545	-120	44.3253	32.1	pool	est. at least 10 feet deep, bedrock walls, numerous boulders, small bubble curtain, suitable holding habitat
36-P	39	28.187	-120	44.2954	32.1	pool	plunge pool with large bubble curtain, bedrock walls, boulders, good holding habitat
36A-P	39	28.2099	-120	44.1742	32.3	pool	est. at least 10 feet deep, steep bedrock walls, some boulders, marginally suitable holding habitat
37-P	39	28.195	-120	44.0733	32.4	pool	est. at least 10 feet deep, steep bedrock walls, some boulders, suitable holding habitat
38-P	39	28.1877	-120	43.9746	32.4	pool	est. at least 10 feet deep, steep bedrock walls, boulders, small bubble curtain, suitable holding habitat
39-P	39	28.2752	-120	43.7475	32.7	pool	est. at least 15 feet deep, steep bedrock walls, large boulders for cover, bubble curtain, good holding habitat
39A-LB	39	28.2752	-120	43.7475	32.7	low-flow barrier	est. falls 8-10 feet high, plunge pool appears to have some blocking boulders, low-flow barrier but not a high-flow barrier
40-P	39	28.3388	-120	43.5928	32.9	pool	est. more than 10 feet deep, steep bedrock walls, boulders, bubble curtain, good holding habitat
40A-LB	39	28.3388	-120	43.5928	32.9	low-flow barrier	est. falls 8-10 feet high, plunge pool appears to have some blocking boulders, may be a low-flow barrier but not a high-flow barrier
41-P	39	28.4702	-120	43.4634	33	pool	est. at least 15 feet deep narrow trench pool, steep bedrock walls, large boulders for cover, bubble curtain, good holding habitat
42-P	39	28.4527	-120	43.484	33	pool	est. more than 15 feet deep narrow trench pool, steep

Appendix Table 1. Potential pools and barriers for spring-run Chinook salmon and steelhead in the Middle Yuba River.							
Name	Latitude Deg (N)	Latitude Minutes	Longitude Deg (W)	Longitude Minutes	RM Loc	Feature	Comments
							bedrock walls, large boulders for cover, bubble curtain, good holding habitat
43-P	39	28.8043	-120	43.0292	33.4	pool	est. at least 15 feet deep pool, steep bedrock walls, boulders, bubble curtain, good holding habitat
44-P	39	28.944	-120	42.846	33.8	pool	appears more than 10 feet deep with good bedrock wall and boulder cover, probably suitable holding pool, but difficult to see
45-P	39	29.382	-120	42.9707	34.4	pool	at least 10 feet deep, steep bedrock walls, boulders, bubble curtain, just d/s box canyon no. 2, good holding habitat
45A-TB	39	29.382	-120	42.9707	34.4	low- & high-flow barrier	low-flow barrier more than 10 feet high, large landslide, probably a high-flow barrier
46-P	39	29.3539	-120	42.7903	34.6	pool	appears more than 10 feet deep with good bedrock wall and boulder cover, probably suitable holding pool, but difficult to see
46A-P	39	29.4375	-120	42.7198	34.7	pool	long, narrow trench pool, est. at least 10 feet, bubble curtain, very steep bedrock walls, probably suitable holding habitat
47-P	39	30.3591	-120	41.3583	36.5	pool	est. at least 10 feet deep, good bubble curtain, steep bedrock walls, boulders, shade, good holding habitat
48-P	39	30.5938	-120	41.1633	36.8	pool	more than 10 feet deep, steep bedrock walls, shade, boulders, overhanging bedrock, good holding habitat
48A-LB	39	30.6099	-120	41.1485	36.8	low-flow barrier	possible low-flow barrier, falls appears about 8-10 feet high, probably not a high-flow barrier
49-P	39	30.7882	-120	40.7629	37.3	pool	est. 15-20 feet deep, narrow and very steep bedrock canyon walls, boulders, good holding habitat
50-P	39	30.8527	-120	40.7419	37.4	pool	est. 15-20 feet deep narrow trench pool, narrow and very steep bedrock canyon walls, boulders, box canyon no. 1, good holding habitat
50A-P	39	31.0479	-120	40.704	37.6	pool	est. more than 10 feet deep narrow trench pool, narrow and very steep bedrock canyon walls, boulders, box canyon no. 1, suitable holding habitat

Appendix Table 1. Potential pools and barriers for spring-run Chinook salmon and steelhead in the Middle Yuba River.							
Name	Latitude Deg (N)	Latitude Minutes	Longitude Deg (W)	Longitude Minutes	RM Loc	Feature	Comments
50B-P	39	31.1805	-120	40.4667	37.9	pool	est. more than 10 feet deep narrow trench pool, narrow and very steep bedrock canyon walls, boulders, assumed suitable holding habitat but very difficult to see
50C-LB	39	31.1805	-120	40.4667	37.9	low-flow barrier	very difficult to see but appear falls may be at least 10 feet tall, probably low-flow barrier but not high-flow barrier
50D-P	39	31.2576	-120	40.3173	38	pool	est. more than 10 feet deep narrow trench pool, narrow and very steep bedrock canyon walls, boulders, assumed suitable holding habitat but very difficult to see
50E-P	39	31.4156	-120	39.7345	38.6	pool	est. more than 10 feet deep narrow trench pool, narrow and very steep bedrock canyon walls, boulders, assumed suitable holding habitat but very difficult to see
51-P	39	31.517	-120	39.5117	38.8	pool	est. more than 10 feet deep narrow trench pool, narrow and very steep bedrock canyon walls, Gates of the Antipodes, assumed suitable holding habitat but very difficult to see
52-P	39	31.5816	-120	39.4132	38.9	pool	steep canyon walls, plunge pool with bubble curtain, shade, assumed suitable holding habitat but difficult to see
53-LB	39	31.5816	-120	39.4132	38.9	low-flow barrier	very difficult to see but appear falls may be at least 10 feet tall, probably low-flow barrier but not high-flow barrier
54-P	39	31.591	-120	39.3865	39	pool	est. more than 10 feet deep narrow trench pool, narrow and very steep bedrock canyon walls, assumed suitable holding habitat but very difficult to see
55-P	39	31.5267	-120	39.2039	39.2	pool	est. more than 10 feet pool, overhanging bedrock wall, assumed suitable holding habitat but very difficult to see

Appendix Table 1. Potential pools and barriers for spring-run Chinook salmon and steelhead in the Middle Yuba River.							
Name	Latitude Deg (N)	Latitude Minutes	Longitude Deg (W)	Longitude Minutes	RM Loc	Feature	Comments
56-P	39	31.4966	-120	39.1851	39.2	pool	est. more than 10 feet deep narrow trench pool, narrow and very steep bedrock canyon walls, assumed suitable holding habitat but very difficult to see
57-P	39	31.4184	-120	39.036	39.4	pool	est. more than 10 feet deep narrow trench pool, narrow and steep bedrock walls, assumed suitable holding habitat but very difficult to see
58-P	39	31.425	-120	37.9619	40.4	pool	est. more than 10 feet deep, steep bedrock walls, bubble curtain, assumed suitable holding habitat but very difficult to see
59-P	39	31.3047	-120	37.371	41.2	pool	est. more than 10 feet deep, sloping bedrock walls, assumed suitable holding habitat but very difficult to see

Appendix Table 2. Potential pools and barriers for spring-run Chinook salmon and steelhead in the South Yuba River.							
Name	Latitude Deg (N)	Latitude Minutes	Longitude Deg (W)	Longitude Minutes	RM Loc	Feature	Comments
3-P	39	17.2299	-121	10.1685	2.7	pool	est. depth at least 10 feet, bedrock walls on both banks, large boulders, good bubble curtain at head of pool, suitable holding habitat
4-P	39	17.2258	-121	9.6831	3.1	pool	est. depth at least 10 feet, bedrock walls on both banks, appears to be deep plunge pool, on sharp bend at head of pool, suitable holding habitat
5-P	39	17.0097	-121	9.6266	3.4	pool	est. depth at least 10 feet but difficult to see in canyon shadow, steep bedrock walls on both banks, small bubble curtain, est. suitable holding habitat
6-P	39	17.0878	-121	8.8869	4.1	pool	est. depth at least 10 feet but difficult to see because of shadow from left bank bedrock wall, trench pool appears as suitable holding habitat
10-P	39	17.3186	-121	8.7062	4.5	pool	est. depth greater than 10 feet, very narrow trench pool, steep bedrock walls on both banks providing shade, suitable holding habitat
12-P	39	17.4074	-121	8.5798	4.6	pool	est. depth at least 10 feet, but in shadow, very long deep pool with steep canyon walls on both banks, suitable holding habitat
13A-P	39	17.6902	-121	8.2399	5.1	pool	est. depth may be less than 10 feet, in shadow, boulders, steep bedrock walls on both banks, bubble curtain but not within plunge pool, could be suitable holding habitat
13B-LB	39	17.6902	-121	8.2399	5.1	low-flow barrier	est. height about 9 feet, complex falls/cascades over large boulders/bedrock with poor plunge pool, possible low-flow barrier but not high-flow barrier
13-P	39	17.6995	-121	8.0836	5.2	pool	est. depth about 10 feet, bedrock walls on both banks, long trench pool, in shade, not a lot of substrate cover, cascade at upper end but in shallower water, marginal but probably suitable holding habitat
14A-P	39	17.7099	-121	7.5358	5.9	pool	site visit, suitable small narrow pool, 8 feet deep, excellent bubble curtain, large boulders and bedrock

Appendix Table 2. Potential pools and barriers for spring-run Chinook salmon and steelhead in the South Yuba River.

Name	Latitude Deg (N)	Latitude Minutes	Longitude Deg (W)	Longitude Minutes	RM Loc	Feature	Comments
14-LB	39	17.7187	-121	7.5309	5.9	low-flow barrier	site visit, 9.5-ft height, boulder at critical location in plunge pool, low-flow barrier but not high-flow barrier
15A-P	39	17.72	-121	7.4676	5.9	pool	site visit, 13-ft depth, small bubble curtain, overhanging bedrock, suitable holding pool but no spawning habitat
15B-P	39	17.6914	-121	7.2606	6.1	pool	site, visit, measured 12 ft deep, bedrock overhang on left bank, marginal spawning and holding habitat
15-P	39	17.6786	-121	7.1708	6.2	pool	site, visit, narrow trench pool measured 16 ft deep, bedrock overhang on both sides, marginal spawning habitat, probably suitable for holding
18-P	39	17.6348	-121	5.9109	7.5	pool	est. more than 10 feet deep, bedrock walls on both sides, boulder, long trench pool, suitable holding habitat
20-P	39	18.0391	-121	5.031	8.5	pool	est. more than 12 feet deep, bedrock walls on both sides, lg. boulders, bubble curtain, suitable holding habitat
21-P	39	18.3465	-121	4.6673	9	pool	est. more than 12 feet deep, gradual bedrock sloped sides, long pool, probably suitable holding habitat
24-P	39	19.7181	-121	0.0401	14.8	pool	est. depth more than 10 feet, bedrock walls on both banks, deepest portion of pool far downstream of bubble curtain, somewhat exposed, marginal but probably suitable holding habitat
28-P	39	20.2213	-120	57.1749	18.6	pool	est. depth over 10 feet, steep bedrock walls on both banks, little substrate as cover, some shade but still relatively exposed, marginally suitable holding habitat
29-P	39	20.5315	-120	56.9565	19	pool	est. depth may be 10 feet, overhanging bedrock on both banks, little substrate as cover, some shade but still relatively exposed, marginally suitable holding habitat
30-P	39	20.2022	-120	56.665	19.5	pool	site visit, excellent characteristics for holding habit,

Appendix Table 2. Potential pools and barriers for spring-run Chinook salmon and steelhead in the South Yuba River.							
Name	Latitude Deg (N)	Latitude Minutes	Longitude Deg (W)	Longitude Minutes	RM Loc	Feature	Comments
							measured 10 ft during site visit, overhanging bedrock, good spawning habitat, boulders, good pool size, shade from steep walls
31-P	39	20.1709	-120	56.6021	19.6	pool	site visit, excellent characteristics for holding habit, measured 7 ft during site visit, overhanging bedrock, good spawning habitat, bubble curtain, boulders, good pool size, shade from steep walls
31A-LB	39	20.1709	-120	56.6021	19.6	low-flow barrier	site visit, low-flow barrier, not a barrier during high-flows, measured height of 8 feet
32-P	39	20.4223	-120	55.0359	21.3	pool	est. depth over 10 feet, steep bedrock walls on both banks, shade from canyon walls, no bubble curtain but assumed suitable holding habitat
33-P	39	20.4072	-120	54.9165	21.4	pool	est. depth over 12 feet, steep bedrock walls on both banks, overhanging bedrock, some boulders, shade from canyon walls, suitable holding habitat
34-P	39	20.802	-120	50.1724	26.6	pool	est. depth over 10 feet, long trench pool, minimal substrate cover, some shade from canyon walls, but somewhat exposed, marginal holding habitat
35-P	39	20.8291	-120	50.0682	26.7	pool	est. depth over 10 feet, long trench pool, minimal substrate cover, some shade from canyon walls, but somewhat exposed, marginal holding habitat
36-P	39	21.2255	-120	48.4159	28.6	pool	est. depth over 10 feet, scour pool on river bend, minimal substrate cover, bedrock overhand on left bank, some shade, somewhat exposed, marginal holding habitat
39A-P	39	21.5528	-120	47.0246	30.8	pool	est. depth approx. 10 feet, in shade, long trench pool with steep bedrock walls, small bubble curtain, assumed suitable holding habitat
39-P	39	21.4396	-120	46.9982	30.6	pool	est. depth over 10 feet, scour pool on river bend, minimal substrate cover, bedrock overhand on left bank, some shade, somewhat exposed, marginal holding habitat

Appendix Table 2. Potential pools and barriers for spring-run Chinook salmon and steelhead in the South Yuba River.							
Name	Latitude Deg (N)	Latitude Minutes	Longitude Deg (W)	Longitude Minutes	RM Loc	Feature	Comments
39B-P	39	21.5146	-120	44.9397	33	pool	est. depth over 12 feet, steep bedrock walls on both banks, overhanging bedrock, some boulders, shade from canyon walls, suitable holding habitat
41-P	39	21.3166	-120	42.8102	35.2	pool	site visit, measured depth 10 feet, steep vertical walls on both banks, suitable holding habitat
42-P	39	21.2748	-120	42.7569	35.3	pool	site visit, measured depth 13 feet, steep vertical walls on both banks, boulder among substrate, suitable holding habitat
43-P	39	21.2153	-120	42.6631	35.4	pool	site visit, measured depth 35 feet, average approx. 25 feet deep, very shaded from steep canyon/bedrock walls, good holding habitat, several doz. fingerling trout observed
43A-TB	39	21.2153	-120	42.6631	35.4	low- & high-flow barrier	site visit, two falls, lower fall 13 feet, upper fall 7.5 feet, lower plunge pool very deep, depth of second plunge pool undetermined, both low and high-flow barrier
45-P	39	21.2416	-120	42.0197	36	pool	site visit, measured depth 15 feet, good cover and good holding habitat, est. more than 100 fingerling rainbow trout observed
45A-TB	39	21.2416	-120	42.0197	36	low- & high-flow barrier	site visit, measured height 17 feet, total (low and high-flow) barrier
45B-P	39	20.7362	-120	41.4152	36.9	pool	est. depth at least 10 feet, good boulder cover, poss. bubble curtain at head of pool
46-P	39	20.7305	-120	40.8581	37.4	pool	cannot est. depth, in shadow, very narrow trench pool with very steep bedrock walls, assumed suitable holding habitat
47-TB	39	20.353	-120	40.7073	37.9	low- & high-flow barrier	est. height more than 10 feet, poor plunge pool, cascades over bedrock, est. total barrier
48-P	39	20.036	-120	40.3035	38.4	pool	est. depth over 20 feet, good holding habitat
48A-TB	39	20.036	-120	40.3035	38.4	low- & high-flow barrier	est. height of lower falls 15 feet, upper falls, 10 feet, total barrier
49-P	39	19.3852	-120	40.181	39.2	pool	est. depth over 10 feet, sloping bedrock sides on both

Appendix Table 2. Potential pools and barriers for spring-run Chinook salmon and steelhead in the South Yuba River.							
Name	Latitude Deg (N)	Latitude Minutes	Longitude Deg (W)	Longitude Minutes	RM Loc	Feature	Comments
							banks, boulder cover, suitable holding habitat
50-P	39	19.2847	-120	40.1963	39.4	pool	est. depth over 15 feet, excellent bubble curtain, broad deep pool with bedrock walls, good holding habitat
51-P	39	19.235	-120	40.1734	39.4	pool	est. depth over 12 feet, steep bedrock walls on both banks, overhanging bedrock, some boulders, shade from canyon walls, suitable holding habitat
51A-TB	39	19.235	-120	40.1734	39.4	low- & high-flow barrier	est. height over 15 feet, poor plunge pool, total barrier
52-P	39	19.2242	-120	40.1464	39.4	pool	est. depth over 12 feet, steep bedrock walls on both banks, overhanging bedrock, some boulders, shade from canyon walls, suitable holding habitat
52A-TB	39	19.2242	-120	40.1464	39.4	low- & high-flow barrier	est. height over 15 feet, poor plunge pool, falls and cascades over bedrock, total barrier
53-P	39	19.2152	-120	40.1252	39.5	pool	est. depth over 12 feet, steep bedrock walls on both banks, overhanging bedrock, some boulders, shade from canyon walls, suitable holding habitat
53A-TB	39	19.2152	-120	40.1252	39.5	low- & high-flow barrier	est. height over 15 feet, poor plunge pool, falls and cascades over bedrock, total barrier
54-P	39	19.2308	-120	40.051	39.6	pool	est. depth over 10 feet, steep bedrock walls on both banks, overhanging bedrock, some boulders, suitable holding habitat
54A-TB	39	19.2308	-120	40.051	39.6	low- & high-flow barrier	est. height over 10 feet, total barrier
55-P	39	19.2542	-120	40.0324	39.6	pool	est. depth over 15 feet, excellent bubble curtain, narrow deep trench pool with bedrock walls, good holding habitat
55A-TB	39	19.2542	-120	40.0324	39.6	low- & high-flow barrier	est. height over 10 feet, total barrier
56-P	39	19.2842	-120	40.006	39.6	pool	est. depth over 15 feet, excellent bubble curtain, broad deep trench pool with bedrock walls, good holding habitat

Appendix Table 2. Potential pools and barriers for spring-run Chinook salmon and steelhead in the South Yuba River.							
Name	Latitude Deg (N)	Latitude Minutes	Longitude Deg (W)	Longitude Minutes	RM Loc	Feature	Comments
56A-TB	39	19.2842	-120	40.006	39.6	low- & high-flow barrier	complex series of falls est. height over 15-20 feet, cascades over bedrock, total barrier
56B-P	39	19.3017	-120	39.9427	39.7	pool	est. depth over 15 feet, sloping bedrock walls, good bubble curtain, good holding habitat
57-P	39	19.2686	-120	39.7797	39.8	pool	est. depth over 20 feet, steep bedrock walls, good holding habitat
57A-TB	39	19.2686	-120	39.7797	39.8	low- & high-flow barrier	est. height over 10 feet, total barrier
58-P	39	19.0362	-120	39.7243	40.1	pool	est. depth over 15 feet, long trench pools with vertical bedrock walls, shade and cover, good holding habitat
58A-P	39	18.9989	-120	39.6537	40.2	pool	est. depth over 10 feet, long trench pools with vertical bedrock walls, shade and cover, good holding habitat